Coastal Services Center
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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STATEMENT OF WORK

Benthic Habitat Mapping from Aerial Optical Remotely Sensed Imagery

July 2005

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List of Acronyms

CO ..... Contracting Officer
COTR ..... Contracting Officer's Technical Representative
CRS ..... Coastal Remote Sensing
CSC ..... Coastal Services Center
FGDC ..... Federal Geographic Data Committee
LIDAR ..... Light Detection and Ranging
NAD ..... North American Datum
NOAA ..... National Oceanic and Atmospheric Administration
QA ..... Quality Assurance
QC ..... Quality Control
RMSE ..... Root Mean Square Error
SOW ..... Statement of Work

Examples from specific projects are in shaded paragraphs.

1 Overview

This section will provide the following: 1) Information about agency requesting acquisition, 2) Project or Program description, 3) Project goal(s), and 4) General description of requirements

National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center (Center) to create digital benthic habitat data from government provided imagery for selected Texas coastal bend bays. The contractor shall submit a firm fixed price proposal detailing how the required products would be produced for the geographic areas under consideration. The contractor shall provide both electronic and hard-copies of their technical and cost proposals.

2 Background

This section will provide a succinct description of the who, what, where, and why of the project. This should be specific information that will fully inform the reader about this effort. This section should describe the specific use of the data and/or services requested.

In this project the Center is working cooperatively with the Texas Parks and Wildlife Department (TPWD) and the Texas A&M University Center for Coastal Studies to develop benthic habitat data, primarily Submerged Aquatic Vegetation (SAV) for several coastal bays. This data will support the state's recently adopted Seagrass Monitoring Program which calls for regional mapping of SAV for status and trends assessment. The Center, Texas A&M, and TPWD have coordinated on the requirements listed in this SOW.

This SOW details the data development requirements to produce benthic habitat data products for the designated coastal bays of Texas's Gulf of Mexico shore. The primary data source for this project is digital multi-spectral camera imagery. The government requires that final benthic habitat products created under the terms of this contract adhere to the specified standards of consistency and accuracy as listed in section 3. These standards are important for ensuring that the data will support change analysis and facilitate habitat monitoring in both local and regional geographies.

The local project partners will provide reference information and logistical support to signature development and validation field work.

3 Requirements

This section will contain the specific requirements for the project. This section must be unambiguous and will be the primary information used by the contractor to prepare their technical and cost proposals.

The government requires image-derived vector and raster benthic habitat data for Texas coastal bend bays. Image processing, feature delineation, and identification shall be accomplished in accordance with the specifications detailed in this SOW.

3.1 Study Area Location and Extent

The project area must be well documented with a written description, how much area is covered by this project (e.g., sq mi, sq km, etc.), a quality map or diagram, and ESRI shapefile(s) in the appropriate projection. Breaking large study areas into smaller units allows the customer to only request products for areas within their budget. It also forms the basis for any incremental mapping that may be required due to different priorities or time constraints.

The shore-ward and sea-ward extents of any benthic mapping project need to be clearly expressed. This is especially true in cases where intertidal resources are of interest such as oyster beds, salt marsh, or mangrove thickets. It is always best to use a fixed boundary if possible, such as an existing shoreline file to avoid the affect of variable tidal conditions.

Benthic habitat vector data shall be generated over eight Texas Coast study areas. The geographic extent of these study areas is as follows: Corpus Christi Bay – ~356 mi^2 , Redfish Bay – ~62 mi^2, Aransas Bay – ~285 mi^2, and Copano Bay – ~158 mi^2, Lower Laguna Madre - ~800 mi^2, Upper Laguna Madre - ~313 mi^2, Baffin Bay - ~232 mi^2, San Antonio Bay - ~ 370 mi^2. Benthic habitat data shall be generated for all estuarine lands below mean high water within the study area. No benthic data is required for the marine side of the barrier beaches. The government will provide digital vector layers in ESRI ArcGIS shapefile format consisting of the boundaries of the study area. The contractor shall provide separate cost proposals for each of the eight areas. The government reserves the right to award a task order for any combination or all of the areas listed above depending on the availability of funds. Figure 1 shows the general location and extent of the study areas.

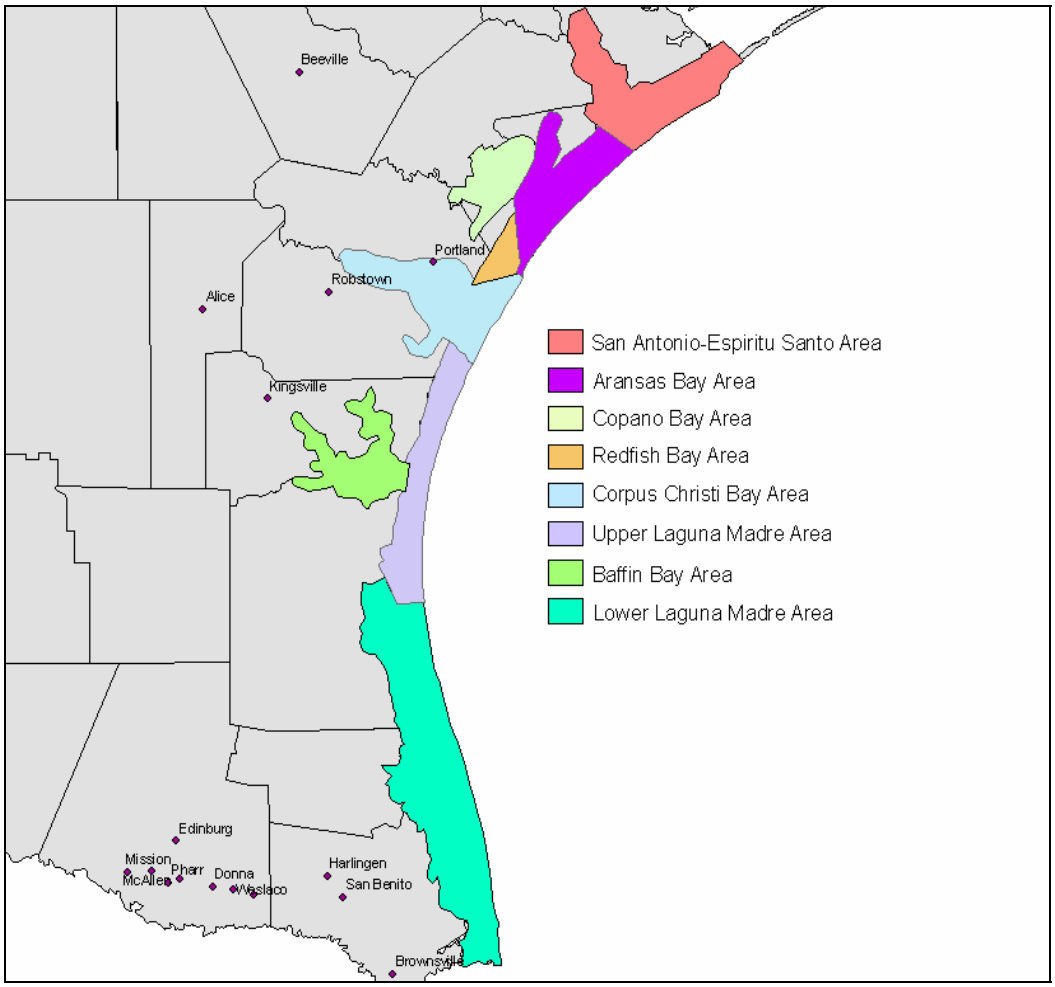

Figure 1: Texas coast study area locations.

3.2 Classification system

This section will detail the specific thematic classification system, if required, for a data product and should address any areas of expected confusion/special concern. There are a variety of classification systems that have been successfully used for benthic mapping. The Coastal Services Center normally uses the SCHEME system of Florida; however, the Cowardin wetland classification system, the CMECS system, and systems used for NOAA corals mapping have also been applied to this kind of mapping. The Center strongly suggests the use of the CMECS system. A copy of the classification to be used should be attached to the SOW or available through a cited reference.
Any special emphasis on a particular class should be mentioned in this section.

*It is essential that the benthic habitat data produced under the terms of this contract be consistent with other NOAA benthic data developed nationwide. For this project, benthic features and habitats should be assigned to habitat classes described in the attached (**Appendix 1**) version of the Florida System for Classification of Estuarine and Marine Environments (SCHEME). Those habitat classes and subclasses anticipated to be found in the study area are identified in **Table 1**; however, all SCHEME classes are to be mapped if encountered*

Table 1. Expected SCHEME Classes for Long Island Benthic Mapping. These categories are the minimum classes likely to be encountered in the study area. **See Appendix 1** for definitions.

Value	Habitat
0	Unclassified
1	Unconsolidated Sediments
211	Continuous Submerged Rooted Vascular Vegetation (SRV)
212	Patchy SRV
2111	Dense Patches of SRV in matrix of continuous sparse SRV
221	Continuous Macroalgae
223	Patchy Macroalgae
321	Bivalve reefs (oyster)
34	Hardbottom
7	Unknown benthic habitat

All applicable SCHEME modifiers (see Appendix 1)

3.3 Minimum Mapping Unit

The decision on what minimum mapping unit to use should be based on the smallest unit of habitat resource that you are concerned with. Sometimes this is based on a jurisdictional or enforcement requirement. In every case, it must be balanced with the effort needed to accurately identify smaller size units. The minimum mapping unit should always be at least several times (4X) the image resolution to ensure reliable results.

For this project the minimum mapping unit (MMU) shall be 0.01 hectares (nominally an area 10m x 10m in size). When deciding whether an area with patches of Submerged Aquatic Vegetation (SAV) is one polygon of patchy SAV or individual continuous SAV polygons, apply the minimum mapping unit of 0.01 hectares.

3.4 Interpretation Rules

In many mapping efforts there arise conditions where an area could be assigned to more than one habitat category. A good example of this is in cases where drift algae has accumulated in a seagrass meadow canopy. These situations require the use of interpretation rules. These rules will govern how such areas are mapped. The rules need to be very clearly articulated and agreed upon by all parties to the project. Clarifying interpretation rules is often a major part of the field signature development process.

The following guidelines are provided as a means of standardizing the photo-interpretation for this task:

A. Outer boundaries of habitats are equally important as the internal structure, patchiness, shapes of sand patches, etc. within habitats.

B. Outer boundaries of habitats are equally important to the internal density categorizations (patchy vs. continuous cover).

C. It is more important to include small isolated habitat patches than similar sized patches that are part of a larger matrix.

D. In cases where the edge of a habitat cannot be determined reliably due to depth, turbidity, glint, or other limiting factor, then the boundary shall be delineated using the best possible line between points where the edge can be reliably determined. This line will be attributed as "fuzzy" in the line coverage provided as a product with the Final Deliverable. In cases where a clear determination of a habitat boundary can be made with confidence, that line will have the attribute "clear".

H. In cases where an area may have continuous or discontinuous SRV (seagrass) cover with macroalgae accumulations in the grass canopy, then the polygon shall be assigned to the appropriate SRV seagrass class and a modifier used to document the presence of macroalgea.

I. In other cases where an area may have multiple small habitat components, then the polygon label shall reflect the majority habitat within the area.

J. Areas that are un-interpretable due to depth shall be assigned to the unknown benthic habitat class.

All habitat delineations will be made with the highest precision possible, to best reflect actual habitat boundaries on the ground.

3.5 Tasks and Process Flow

It is generally wise to include a generalized process flow in an SOW if the methods are in common use and the project consists of operational work that is within the normal practice of the industry. By listing the tasks and processes, the number of field visits, any project dependencies, and other elements are explicitly presented for the contractor to develop into a plan or as points of negotiation. The level of detail in the proposed tasks and process flow should be general to allow opportunities for innovation by the vendor.

The contractor shall perform the following tasks:

1. *Establish a spatial control network to rectify aerial photography. This should draw from existing sources, such as ortho-photos, digital elevation models (DEMs), ground control points (GCPs), etc., as much as possible. The spatial accuracy and source of any control used shall be reported to the government.*

2. *Scan aerial photography required for benthic mapping using photogrammetric quality scanner. The photography shall be scanned to produce a pixel resolution of 0.3 meters (1 foot).*

3. *Conduct aero-triangulation and ortho-rectify scanned aerial photography using control described in item #1 above.*

4. *Create color-balanced, ortho-rectified mosaic of the study area at 0.6m (2 ft) pixel resolution from the individual photographs.*

5. *Subset the mosaic according to a grid tile system to be provided by NYDOS.*

6. *Conduct additional field signature development and GCP measurement visit to the study area (first trip).*

7. *Incorporate summer 2002 GPS controlled field observations (provided by the government) for signature development*

8. *Conduct additional field signature development and GCP measurement visit to the study area (first trip).*

9. *Compile detailed draft benthic habitat vector polygon data using the SCHEME classification system (as detailed in Table 1 and Appendix 1).*

10. *Provide digital copy of the draft benthic data set to the government two weeks prior to contractor's field validation. The government will provide comments to the contractor.*

11. *Conduct field visit to the study area to validate this draft benthic habitat data set (second trip).*

12. *Review and edit line and polygon coverages and attribute tables to ensure that the data set has high spatial detail, is logically consistent, and meets the specified thematic and spatial accuracy requirements.*

13. *Deliver provisional benthic habitat data sets to the government for final thematic and spatial validation and acceptance.*

14. *Incorporate government comments into the final benthic habitat data product (if necessary).*

3.6 Thematic Accuracy

Thematic accuracy involves whether the map units are correctly identified. This is often reported from both a producers and users perspective. Producer's accuracy reflects how many units identified by the mapper were correct when visited in the field. Users' accuracy reflects how many units observed in the field were correctly identified in the map. These can also be expressed as errors of Commission or Omission.

Thematic accuracy requirements usually involve an overall minimum accuracy standard for all classes in the data as well as a "conditional accuracy" which is the accuracy of an individual category in the data. For benthic habitat data derived from remote sensing overall accuracies of 80-85% are normally the upper limit. Conditional accuracies below 70% may not support effective use of the data.

In mapping projects where some habitats are of greater concern, a thematic accuracy requirement for just those classes is sometimes used.
If funding permits, it is usually good practice to have the contractor conduct their own thematic accuracy assessment and then report the results as part of their delivery.
In other cases it may be more feasible for the customer to do this assessment.
Regardless of which approach is taken some validation by the customer is important to project success

It will be the responsibility of the contractor to ensure that the delivered benthic habitat data set meets the thematic accuracy specifications described below. The contractor shall describe the methods they will take to ensure acceptable thematic accuracy as part of their QC plan described in section 3.4. In addition, the thematic accuracy of the benthic data will be verified by field observations conducted by the government prior to acceptance of the final data product. Stratified random sample points will be generated by the government and a representative subset of these will be observed in the field to determine the spatial, categorical, and overall accuracies.

The habitat polygons themselves will serve as the sample units. The thematic accuracy of the polygons shall be determined based on observations inside of polygon boundaries (> 5m or ½ the distance into a polygon, whichever is smaller) to avoid edge effects. Thematic accuracy of the final data will be determined by development of an error matrix and calculation of Kappa coefficients (Congalton and Meade, 1983; Hudson and Ramm, 1987) based on comparison of field observations to the Contractor-generated benthic habitat data for predetermined polygons.

The minimum acceptable field/map accuracy limits are 90% for each individual habitat type, and 95% overall for baseline benthic habitat at the SCHEME 2-digit subclass level from a "users," as well as a "producers" perspective as defined by Story and Congalton, 1986[2].

The contractor shall provide a report detailing how they achieved the above accuracies. This report will contain the error matrices, field observation records, observation methods etc. from the contractor's field validation effort in a format to be provided by the government. Data not meeting minimum quality assurance standards shall require additional processing by the contractor, at the contractor's expense, and subsequent field checks prior to acceptance of the data by the government.

[2] This and other reference works provide more detail on the topic of thematic accuracy.

3.7 Spatial Accuracy

Spatial accuracy is normally not a component of a benthic mapping project. Normally this requirement is addressed within the context of the image or data collection effort. It is usually assumed that any raster or vector habitat products derived from the raw image data have the same spatial accuracy as that native data. If there are cases where this cannot be assumed a statement about the spatial accuracy requirement should be included here as well as general discussion of the roles of the contract parties and the approaches proposed for determining whether the products meet contract specifications.

3.8 Records and Metadata

Many non-federal groups are not familiar with the FGDC standard. Some education may be necessary for them to develop this type of metadata. Supplying the contractor with examples is helpful. Project elements where metadata is especially important are in thematic and spatial validation, data development methods, and field data collection.

The contractor shall document all delivered data and data products (including options if exercised) according to Executive Order 12906 (http://www.fgdc.gov/publications/documents/geninfo/execord.html) Specifically, the contractor shall deliver for all data and data products, metadata records which detail all flight lines, flight dates and times, datums, reprojections, resampling algorithms, processing steps, field records, and any other pertinent information. The metadata records shall conform to the Content Standards for Digital Geospatial Metadata (FGDC-STD-001-1998) as published on May 1, 2000, by the Federal Geographic Data Committee (FGDC) or to any format that supersedes it as determined by the FGDC. (http://www.fgdc.gov/metadata/csdgm/). Profiles and extensions to the standard that have been endorsed by the FGDC shall be used if they are applicable to the data or data products. The metadata records shall contain any and all elements, including those that are considered optional, wherever applicable to the data or data product. The metadata record shall contain sufficient detail to ensure the data or data product can be fully understood for future use and for posterity. The metadata records shall be delivered free of errors in both content and format as determined by the metadata parser (mp) program developed by the United States Geological Survey or an equivalent. The metadata records will be subject to review and approval prior to final acceptance by the Government.

3.9 Kickoff Meetings

The face-to-face kick-off meetings are especially important to clarifying major project tasks and sequences. They are also very useful as an opportunity to establish a common understanding of any interpretation rules to be used in the project.

The contractor shall attend a kickoff meeting at the designated site within 30 days of contract award unless otherwise agreed. This meeting will serve as an information exchange and planning meeting for future activities such as delivery of government furnished equipment (GFE) and field trips. If the Work/QC plan has been delivered and reviewed it may be a point of discussion during this meeting

3.10 Contractor Coordination

Effective communication with the contractor is essential to project success. Over time the impetus for the conference calls can wane. Nevertheless, should a problem arise, the communication maintained by the calls helps in resolving it.

Communication and coordination between both the contractor and the Government is considered vital to the satisfactory accomplishment of this SOW. The Contractor shall expect periodic interaction with the Government to ensure clear understanding of the anticipated products and satisfactory progress in the delivery of products.

The contractor shall submit monthly progress reports to the Government summarizing progress made and problems encountered. After submittal of each of these reports the contractor shall schedule a conference call with the government to discuss the progress of the project and any issues that need to be addressed. The contractor shall prepare and distribute an agenda for the call and shall distribute the meeting minutes within 5 days of the conclusion of the call.

3.11 Deliverables

This section contains the complete list of deliverables associated with the specific project. Each deliverable must include a proposed measure of acceptability. The quality control plan (item 2) is one of the most important documents in the project. A robust QC process on the part of the contractor will save much effort in reviewing deliverables by the customer. If specific protocols are required for the project then these should be identified in the Work Plan.

The Contractor shall complete and provide the following items specified by the government upon contract award. All digital raster, vector, and field data produced by the contractor shall be delivered in a Universal Transverse Mercator (UTM) projection, zone 18 with a GRS 1980 spheroid and North American Datum 1983. The contractor shall assign each of the below deliverables a percentage of the entire task order that they represent. The contractor will be able to invoice for that amount only once that deliverable has been accepted by the government.

1. *Quality Control Plan, Field Validation Plan, and Work Plan.*

2. *Written monthly progress reports, which shall include activities conducted for the month, problems encountered, activities planned for the coming month, and progress toward overall completion of the contract. These reports shall be produced using either MS Word or WordPerfect, and delivered via email attachment to the COR. These reports shall conform to a template provided by the COR and be followed by conference calls between the contractor and the government initiated by the contractor.*

3. *Draft Base and Option 1 digital benthic habitat data products. The draft products shall be provided in an ESRI shapefile vector and ERDAS imagine raster format via CD-ROM*
   The vector data shall reflect the high digitizing precision required to accurately portray conditions on the ground. At a minimum these shapefiles shall have the characteristics described in the requirements section. The contractor may break this deliverable into sub-deliverables to assist with their invoicing process if desired.

5. *Contractor Final digital benthic habitat products meeting government specified accuracies with associated metadata. These data sets shall include the results of the contractor's field validation. The final products (both raster and vector) shall be delivered in the same projection and media as the first draft data set.*

6. *Field thematic accuracy validation report and spatial field observation database. This report shall describe in detail the methods used to conduct the validation, the individual sample site observations, and error matrices. The field observation database shall be designed according to the template provided by the government. The field report shall not exceed ten (10) pages in length and be provided in either MS Word or WordPerfect format (1 paper copy and 1 CD-ROM).*

7. Final digital benthic habitat products incorporating results of government's validation. The final products shall be delivered in the same projection and media as the first draft data set.

8 Final report including project narrative, complete processing documentation, and descriptive summary of results. This report shall be no more than ten (10) pages in length, produced using either MS Word or WordPerfect, and delivered in hard copy and on CD-ROM (1 paper copy and 1 CD-ROM).

3.12 Product Delivery Schedule Guidance

If the government has any required delivery dates or time constraints they will be put in this section. The delivery schedule guidance is provided with estimated timelines to ensure understanding of the required products and timeframes for anticipated completion. Otherwise the contractor will propose the schedule. This section should also address time allocation for the re-delivery of unaccepted deliverables.

The contractor shall develop a timeline for benthic data product development so as to facilitate its rapid incorporation into the coastal management processes. This timeline shall be provided in Microsoft Project format. The following product delivery schedule is provided with estimated timelines to ensure understanding of the required products and timeframes for anticipated completion.

1. Quality Control Plan, Work Plan, and Field Validation Plan (within 14 days of task order award).

2. Kick off meeting (within 30 days of task order award)

3. Monthly progress reports (within 7 days of the end of each calendar month for the duration of the task order).

4. Multi-spectral imagery of the selected study areas.

5. Draft benthic habitat data products (2 weeks prior to contractor's validation field trip).

6.Contractor Final benthic habitat data products (by July 31, 2006 to allow for government's final validation). The government will have 30 days in which to conduct its field validation and report on the results back to the contractor.

6. Final benthic habitat data products (one month prior to the end of the task order completion period).

7. Final report (one month prior to the end of the task order completion period).

3.13 Product Delivery Addresses

The deliverables listed above shall be delivered to the following address.

****
1234 South Anywhere Avenue
Charleston, SC 29405
Attn:

Other Agency or agent

4 Options

This section provides a mechanism to receive price quotes from vendors from which an acceptable/fundable/affordable mix of deliverables can be selected. Variables which can be addressed using this method include:

- Products with variable accuracies
- Products from multiple geographic expanses – i.e. a list of counties
- Products with variable detail classifications- i.e. 0.5 m minimum mapping unit vs. 1.0 m minimum mapping unit

Option descriptions shall be detailed enough for the contractor to provide a realistic cost proposal. The choice of options should also be logical. Two common examples of the use of options are when data sources are different (analog vs. digital imagery) or when products are different (raster vs. vector).

Option 1 is a quantitative determination of patchiness within the SAV classes (SCHEME codes 21 and 22). This will be a pixel-based thematic raster product (i.e. no minimum mapping unit) of the individual SCHEME categories within the polygon. For example in a discontinuous SRV bed the pixels would likely consist of SRV and unconsolidated bottom. There is no accuracy requirement for this product. Option 1b requests that the percent SAV cover (patchiness) be determined for each class 212, 2212, and 2222 polygons in the Base product and this value added to the attributes of that product.

5 Product Terminology/Glossary

This section is intended to ensure all unique product terms including *draft, revised,* and *final* are explicitly defined and understood by all parties. This list is not exhaustive and great care should be taken to include all potentially ambiguous terminology associated with the specific project.

DRAFT Data Sets - These are vector benthic habitat perimeter data (both line and polygon) that is logically complete, fully attributed, and ready for the contractor's field accuracy assessment, as well as the thematic raster within the continuous and discontinuous classes. It represents the best that the analysts can produce, has been through all internal QA/QC processes, and is anticipated to meet the 80% categorical and 85% overall thematic accuracy requirements. It shall be provided to the government for general comments 2 weeks prior to the contractor's field assessment trip.

CONTRACTOR FINAL Data Sets – These are DRAFT vector and raster data sets that have been evaluated during the contractor's field assessment. Any errors detected during that assessment have been corrected and any final edits completed. These data meet the task order accuracy requirements and documentation has been prepared that demonstrates this to the government.

FINAL Data Sets – These are Contractor Final data that has been evaluated during the government's field validation and meets the contract accuracy requirements. Any errors detected during the government's final validation have been corrected by the contractor. This data set will consist of both a polygon vector coverage and a thematic raster.

6 References

Any background literature, protocol documents, or methods that are important to understanding the issue or for more detail on specific collection parameters should be listed here.

Congalton, R. G., and R. A. Meade, 1983; A Quantitative Method to Test for Consistency and Correctness in Photointerpretation. Photogrammetric Engineering and Remote Sensing, Vol. 49, No. 1, pp. 69-74.

Story, M., and R. G. Congalton, 1986; Remote Sensing Brief - Accuracy Assessment: A User's Perspective. Photogrammetric Engineering and Remote Sensing, Vol. 52, No. 3, pp. 397-399.